AE

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H05B 3/26

A1

(11) International Publication Number: WO 97/09866

(43) International Publication Date: 13 March 1997 (13.03.97)

(21) International Application Number: PCT/IL96/00096

(22) International Filing Date: 3 September 1996 (03.09.96)

(30) Priority Data:

115198	7 September 1995 (07.09.95)	IL
118739	25 June 1996 (25.06.96)	IL

(71) Applicant (*for all designated States except US*): BAR-KESER PROJECT MANAGEMENT INITIATIVES AND ECONOMIC CONSULTANTS (1991) LTD. [IL/IL]; 97 Jaffa Road, 91999 Jerusalem (IL).

(72) Inventor; and
(75) Inventor/Applicant (*for US only*): BIKHOVSKY, David [IL/IL]; D.N. East Benjamin, 90627 Ofra (IL).

(74) Agent: COHN, Ilan; Reinhold Cohn and Partners, P.O. Box 4060, 61040 Tel-Aviv (IL).

(81) Designated States: AL, AM, AT, AU, AZ, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

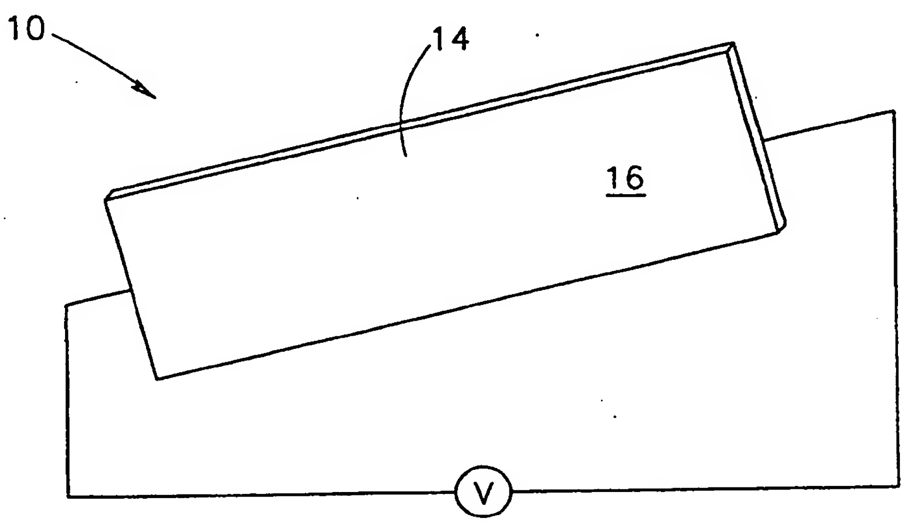
Published

With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: ELECTRIC HEATING DEVICES AND ELEMENTS

(57) Abstract

Heating device having a substantially flat heating element with specific dimensions of length and width, is provided. Heating devices of the invention may be implemented in domestic heaters, in food cooking devices, etc. Also provided is a method for designing heating elements for use in such devices.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AM	Armenia
AT	Austria
AU	Australia
BB	Barbados
BE	Belgium
BF	Burkina Faso
BG	Bulgaria
BJ	Benin
BR	Brazil
BY	Belarus
CA	Canada
CF	Central African Republic
CG	Congo
CH	Switzerland
CI	Côte d'Ivoire
CM	Cameroon
CN	China
CS	Czechoslovakia
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
FI	Finland
FR	France
GA	Gabon
GB	United Kingdom
GE	Georgia
GN	Guinea
GR	Greece
HU	Hungary
IE	Ireland
IT	Italy
JP	Japan
KE	Kenya
KG	Kyrgystan
KP	Democratic People's Republic of Korea
KR	Republic of Korea
KZ	Kazakhstan
LI	Liechtenstein
LK	Sri Lanka
LR	Liberia
LT	Lithuania
LU	Luxembourg
LV	Latvia
MC	Monaco
MD	Republic of Moldova
MG	Madagascar
ML	Mali
MN	Mongolia
MR	Mauritania
MW	Malawi
MX	Mexico
NE	Niger
NL	Netherlands
NO	Norway
NZ	New Zealand
PL	Poland
PT	Portugal
RO	Romania
RU	Russian Federation
SD	Sudan
SE	Sweden
SG	Singapore
SI	Slovenia
SK	Slovakia
SN	Senegal
SZ	Swaziland
TD	Chad
TG	Togo
TJ	Tajikistan
TT	Trinidad and Tobago
UA	Ukraine
UG	Uganda
US	United States of America
UZ	Uzbekistan
VN	Viet Nam

ELECTRIC HEATING DEVICES AND ELEMENTS

FIELD OF THE INVENTION

The present invention relates to electric heating devices in general and in particular to heating elements useful in such devices.

BACKGROUND OF THE INVENTION AND PRIOR ART

Heating devices, in household, industrial or other use have typically a heating element which is embedded within the device and which then transfers heat by radiation, convection or conductance to an output surface of the device. The temperature at the output surface of the device is thus much lower than the working temperature of the heating element. There is usually a very big temperature drop between the temperature of the heating element which ranges from 100's to 1,000's°C, depending on the type of device, to a temperature at the output surface which may be 60–90°C for household heating devices to 120–300°C for household cooking and baking devices.

Heating devices come in a large variety of form and shape. For example, one type of electric heating devices have a bare heating element typically fashioned as either a band or a wire made from an alloy containing nickel and/or chromium and which typically reach working temperatures of about 400–1600 °C. The heat generated by such heating elements is dissipated to the surrounding medium by mainly one or any combination of three heat transfer mechanisms, these being radiation, natural or free convection or forced convection, e.g. by the use of a ventilator. Such heating devices enjoy the advantages of being inexpensive, small, of a relatively low weight and having a long lifetime. However, they suffer from a drawback arising out of the high working temperature of their heating elements which poses a safety hazard.

In another type of electric heating devices, commonly known as electric radiators, the hazards associated with the bare heating element type heating devices are eliminated by submerging a heating element in a reservoir of oil or a similar liquid employed for transferring the heat generated by a heating element to the external walls of the radiator. Typically, the output temperature of a domestic heating radiator is about 70°C whereas the working temperature of its heating element is 700°C or above. As is well known, electric radiators suffer from the disadvantages that they are expensive, heavy, and relatively inefficient.

U.S. Patent 2,600,486 discloses an electric heating element which comprise a flexible conducting metal sheet in which slits are cut so as to form an elongated relatively narrow torturous flow path for electric current. A similar kind of heating device is also disclosed in U.S. Patent 3,584,198. U.S. Patents 3,525,850 and 4,551,614 disclose an electric heater comprising elongated heating elements in the form of corrugated metallic ribbons which are heated to a temperature of about 1200–1800°F (about 650–1000°C). U.S. Patent 2,719,213 discloses a heating device in the form of a flat panel which comprises an electric conductor arranged in a plane between two different non conducting sheets or layers, French Patent Specification 975,038 discloses heating element in the form of arrogated plates Another

heating panel is disclosed in U.S. Patent 3,244,858 wherein an electric heating wire is arranged in a plane to track a zig–zag path over both sides of a non conducting planar core. U.S. Patent 4,203,198 discloses a planar heating device which employs a heating element arranged in a plane to track a torturous path and sandwiched between two sheets of fiber glass. Another heating device with a heating element arranged in a plane between two insulating sheets is disclosed in Australian patent Specification 159,144. U.S. Patent 4,032,751 discloses a planar heating element utilizing electrically conducting carbonaceous pyropolymers. An electric planar heating device intended for use as an electrical bandage is described in U.S. Patent 2,712,591, wherein an electrically conducting ribbon is embedded in a resilient strip of insulating material. A flexible circuit heater which can be used within clothing or the like is disclosed in U.S. Patent 4,948,951, utilizing an electrically conductive strip made to track a torturous path within a flat flexible member. U.S. Patent 4,665,308 discloses an electrical heating element for incorporation in a lining of a clothing item which makes use of a ductile insulated metal wire fixed to a metal sheet.

GENERAL DESCRIPTION OF THE INVENTION

It is an object of the invention to provide a novel heating device with no or very little temperature gradient between the heating element and the outer surface of the device.

It is an object in accordance with some embodiments of the invention to provide a heating device wherein the heating element constitutes the heat dissipating, output surface of the device.

It is an object in accordance with some other embodiments of the invention to provide a heating device wherein the heating element is embedded or forms a structural element of a household object serving also a purpose other than heating.

It is furthermore an object of the invention to provide domestic enclosure heating devices, electric cooking devices and therapeutic heating devices having characteristics in accordance with the above objects.

It is furthermore an object of the invention to provide a method for designing in constructing such heating devices.

Other objects of the invention will be clarified after reading the text below.

The present invention relates to domestic, industrial and other heating devices suitable for a wide range of applications including, but not limited to, heating enclosed spaces, heating food, therapeutic purposes, and the like and relates to electric heating elements for use therewith.

In the following, use will at times be made of the term *"heating device"*. This term should be construed in a broad manner mainly to relate to any device or object wherein one or its intended uses is heating. In accordance with the prior art, a heating device is typically a dedicated device designed for a single function, namely heating. However, in accordance with the invention, by some embodiments thereof, the heating device is embedded or forms parts of objects having an entirely different purpose. For example, the heating element may form a structural component in a furniture thus having dual role in such an object. Thus, the term *"heating device"* should be understood, depending on the context, as referring also to such dual role objects.

The present invention allows in fact to design heating elements for every purpose, need and to any desired form. This unique feature of the invention allows to incorporate the heating element as a structural element or as an add–on in a large variety of objects including various domestic constructional units (e.g. door frames) furnitures, etc.

The heating element of the invention dissipates heat at practically any desired power rating, with a working temperature of the element which is way below the working temperature of the heating element of prior art devices operating with a comparable power rating. For example, in a heating device of the invention suited for domestic interior heating, the heating element may be designed to operate with a working temperature of 70–80°, which is the conventional output temperature of heating devices,

and accordingly the heating element may be placed and form the external, output surface of the heating device.

In order to avoid electric shock hazards, the heating element of the invention may be designed to operate under relatively low voltage, ranging, depending on the application, between 1 V or even below to about 24 V (which is the conventional upper limit in low voltage systems).

In accordance with the present invention the heating element to suit a specific application is designed on the basis of novel developed relationships which allow to match dimensions (length, width and thickness) of a heating element, to a desired voltage and power rating. These relations allow to choose the appropriate heating element to suit a specific application. Given the fact that the heating element operates at a relatively low temperature, it may be made from a wide variety of alloys, which could not be used in conventional (prior art) heating devices, such as aluminum, stainless steel, copper, etc.

According to the general teaching of the invention, there is thus provided a heating device having an output surface through which heat is dissipated and comprising a heating element operating under an electric potential U for dissipating heat power rating W, the heating element being characterized in that:

(i) the heating element, made of an electric conductive material of a specific resistivity ρ is substantially flat and has a substantially rectangular cross section, the heating element having a length l along which the electric potential U falls, a width b and a thickness δ so as to define at least one major surface of the heating element having an area bl; and

(ii) the length l, the width b and the thickness δ of the heating element being such so as to allow generation of the heat power rating W under the electric potential U and the current I, where $W = UI$, by satisfying the following relations (1) and (2):

$$l \geq k_1 \; U \sqrt{\frac{\delta}{\rho}} \qquad (1)$$

$$b \geq k_2 \, l \sqrt{\frac{\rho}{\delta}} \qquad (2)$$

wherein k_1 is 200 and k_2 is 0.2 with the units of length l being meters, the units of the width b and the thickness δ being millimeters, and the units of the specific resistivity ρ of the heating element being Ohm•mm²/m.

Where the electric heating device is employed to heat air at an initial ambient temperature of about 20°C (room temperature) to a temperature of 100°C or more, or to heat a water based medium consisting of at least 50% water which is initially at room temperature, to a temperature up to about 50°C, k_1 will thus be within the range of 200–600° and k_2 will be within the range of 0.2–0.6.

In case the heating device of the invention is employed to heat air at room temperature to a temperature up to about 90°C or less, k_1 will typically be above 600 and k_2 above 0.6.

The present invention allows to design a heating element to suit, practically, any desired need. At times, the length and width of the elements are predetermined by the shape of the heating device, leaving a certain degree of freedom in the choice of alloy (and hence of the specific resistivity ρ) and thickness of the element. This may be the case, for example, in heating devices in which the heating element is incorporated in another object, e.g. a piece of furniture. In other cases, the material and hence the specific resistivity ρ is predetermined leaving a degree of freedom other physical parameters, being one of the length, width and thickness. This may be the case, for example, in heating devices where the heating element is intended to come into direct contact with a food item where, the alloy from which the heating element is made, will typically be stainless steel. These are but examples, but it is clear that it is possible, for practically all applications, to find, based on the above relations (1) and (2)

a combination of parameters which allow to design an appropriate heating element.

By a specific aspect of the invention there is provided a heating device comprising a heating element incorporated as a structural element in a stationary object such as a piece of furniture, door or window frames, etc. In accordance with a further specific aspect of the invention there is provided a heating device comprising a heating element embedded or enclosed within such a stationary object.

Another specific aspect of the invention concerns a device for food heating. The term *"food heating"* should be understood as referring to one of a variety of heat–based food processing techniques including cooking, baking or grilling.

The novelty in the cooking device of the invention is in that it comprises a metal body which is either in contact with the food or which is in proximity with food without any object between it and the food, said metal body serving as a heating element being thus connected to a power source for passing heating electric current therethrough.

In accordance with one embodiment of this latter aspect, there is provided a cooking device for heating of liquid food, comprising a metal vessel for holding the food having metal walls serving as heating elements, and comprising a power source for passing low voltage, high electric current therethrough, thereby heating the liquid food contained therein. The electrical current parameter useful for such an application are typically voltage between 1.0 V – 12 V with a power rating of 1–2 KWatt.

In accordance with another embodiment of the latter aspect, there is provided a device for heating solid food items, in which the solid food items are placed in direct contact with a metal plate, said metal plate serving also as a heating element and being connected to an electric power source for passing a heating electric current therethrough.

In accordance with yet another embodiment of the latter aspect, there is provided a device for heating food by means of heat irradiation onto the food, comprising a food–containing enclosure having one or more metal

walls, at least one of said metal walls serving as a heating element to heat said enclosure and being connected to a power source for passing a heating electric current therethrough.

By a further aspect the present invention provides a heating device adapted to be worn or held on a body part for heating of that body part. By one embodiment of this aspect, such a device comprises a cloth or a cloth base matrix with a heating element embedded therein, the heating element having the above specifications. In accordance with another embodiment, the device comprises a liquid or gel–containing enclosure having pliable walls and containing therein a heating element, being a heating element having the above characteristics.

By yet another aspect of the invention there is provided a method for designing a heating element for implementing into a heating device for a predetermined application, comprising the steps of:

(a) specifying a desired power rating W and a range of operating potential U of the heating element in accordance with the predetermined application;

(b) specifying a list of at least one electrically conductive material in which the heating element can be formed in accordance with said application;

(c) specifying at least one of the length and the width of the heating element in accordance with said application;

(d) specifying the minimum thickness of the heating element in accordance with said application;

(e) specifying a desired working temperature of the heating element to suit said application;

(f) determining:

(i) a material from which the heating element is formed from amongst said list;

(ii) a thickness of the heating element which is at least equal to the minimum thickness, and

(iii) the other of the length, width and thickness of the heating element, so as to satisfy the following relationships:

$$l \geq k_1 \, U\sqrt{\frac{\delta}{\rho}} \tag{1}$$

$$b \geq k_2 \, I\sqrt{\frac{\rho}{\delta}} \tag{2}$$

wherein the dimensions of l, b, U, I, δ and ρ are as given above and k_1 and k_2 have the above values.

(g) verifying that the actual achieved working temperature is identical to the desired working temperature; and if different

(h) repeating steps (f) and (g) for at least one of different materials, thicknesses or the other of the length and the width, until the actual working temperature matches said desired temperature.

It will be appreciated that the actual working temperature in a heating device depends on a variety of factors including the nature of the heating device environment, the exact geometry, etc., and therefore it is not always possible to predict the working temperature entirely on theoretical considerations.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the present invention and to show how the same may be carried out in practice, and solely by way of example, reference will now be made to specific embodiments with occasional reference to the accompanying drawings, in which:

Fig. 1 is a schematic view of an electric heating device constructed and operative according to the teachings of the present invention;

Fig. 2 is a perspective view of an electric heating device for providing a warm air flow around a bed;

Fig. 3 is a perspective view of an electric heating device for heating a children's bedroom;

Fig. 4 is a perspective view of an electric heating device for heating a lounge;

Fig. 5 is a view of a fragment of a domestic heating device wherein a heating element is embedded in a construction element such as a door frame;

Fig. 6A is a perspective view of such an element;

Fig. 6B shows the same element with the front wall removed to show the heating element;

Fig. 7 is a perspective view of an electric heating device for heating food;

Fig. 8 shows a food heating system in accordance with another embodiment of the invention comprising an interchangeable heating element construction for use in a variety of food heating applications;

Fig. 8A shows a system with a heating element intended for baking, heating of frozen food, etc. contained in the enclosure under the heating element;

Fig. 8B shows a cross–section along lines 8B–8B in Fig. 8A;

Fig. 8C is a cross–section through lines 8C–8C in Fig. 8A;

Fig. 8D shows the same system with a heating element intended for frying of meat or the like;

Fig. 8E shows a cross–section through lines 8E–8E in Fig. 8D; and

Fig. 8F shows the attachment end of the heating element in Fig. 8C which attaches to the power supply outlet member;

Fig. 9 shows a therapeutic heating device in accordance with the invention;

Fig. 9A is a perspective view of a therapeutic heating device;

Fig. 9B shows the device of Fig. 9A in use in heating a portion of an individual's arm;

Fig. 10 shows another embodiment of a therapeutic heating device:

Fig. 10A is a planar view of the device;

Fig. 10B shows a device of Fig. 10A attached to an individual's leg;

Fig. 11 shows how the embodiment of a therapeutic device for heating an individual's elbow region;

Fig. 12 shows a therapeutic device for heating an individual's lower back;

Fig. 12A is a perspective view of the device;

Fig. 12B shows the device in use;

Figs. 13 and **14** show other embodiments of therapeutic devices of the invention; and

Fig. 15 shows a perspective view of a device for heating a body of air by convection.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE PRESENT INVENTION

With reference now to the drawings, Fig. 1 shows an electric heating device, generally designated **10** connected to a source of electric energy **12** implemented as any one of a wide range of conventional DC and/or AC sources. Hence, the source of electric energy **12** can be implemented as a mains supply, a battery, a down-step transformer, and the like depending, *inter alia*, on the environment in which the electric heating device **10** is deployed.

In its simplest form, the electric heating device **10** is implemented as an electrically conductive heating element **14** fashioned as a relatively thin, generally rectangular cross sectioned, plate or band **16** having a length "l", a breadth "b" and a thickness "δ", and working under electric potential U and dissipates power at power rating W. The relationship between these parameters is in accordance with relations (1) and (2) above.

The heating element 14 is preferably prepared from materials which possess the following properties: relatively high conductivity, relatively low specific weight, high availability, a capability of being rolled in a rolling process to relatively thin thicknesses of between about 0.01 mm to about 0.2 mm, and the like. In case where the element should serve as a structural element of an object, it may be desired that the material will have the needed strength for the additional fraction of the featured element. It is a particular feature of the invention that a wide range of materials which can be suitably employed as heating element 14 include, but are not limited to, steel with a specific resistivity ρ of between about 0.1 to about 0.13 Ohm•mm^2/m; spring steel with a specific resistivity ρ of between about 0.24 to about 0.4 Ohm•mm^2/m; transformer steel with a specific resistivity ρ of between about 0.5 to about 0.65 Ohm•mm^2/m; stainless steel with a specific resistivity ρ of between about 0.7 to about 0.8 Ohm•mm^2/m; copper based alloys with a specific resistivity ρ of between about 0.017 to about 0.025 Ohm•mm^2/m; gold with a specific resistivity ρ of between about 0.02 to about 0.03 Ohm•mm^2/m; titanium with a specific resistivity ρ of between about 0.4 to about 0.6 Ohm•mm^2/m; aluminum with a specific resistivity ρ of between about 0.035 to about 0.05 Ohm•mm^2/m; and others. It should be noted that the specific resistivity of some alloys, such as aluminum, changes considerably with a change in temperature, and thus should be factored when designing the element.

The following Tables I – IV, show examples of physical dimensions (thickness – δ, length – l, width – b, and weight – G (in grams)) of heating elements in accordance with the present invention for an electric heating device operating under a voltage of 220 V for dissipating a power rating of 1 Kw for heating an air based medium at an ambient temperature of about 20° while maintaining a surface temperature of the heating element of about 70–80°. Table I shows some examples of physical dimensions where the heating element is fashioned from carbon steel having a specific resistance of 0.13 Ohm•mm^2/m; Table II shows examples where a heating element is fashioned from spring steel with a specific resistance

of 0.4 Ohm•mm²/m; Table III shows examples where a heating element is fashioned from a transformer steel with a specific resistance of 0.6 Ohm•m-m²m; and Table IV shows examples where a heating element is fashioned from aluminum with specific resistance of 0.027 Ohm•mm²/m.

Table I

δ (mm)	l (m)	b (mm)	G (g)
0.015	52	9,1	56,7
0,038	73	6,5	113
0,05	95	5,0	190
0,10	133	3,8	404
0,20	185	2,7	799

Table II

δ (mm)	l (m)	b (mm)	G (g)
0,015	29,6	16,4	58
0,030	41,5	11,7	116
0,05	54,0	9,0	194
0,10	76,0	6,6	400
0,20	106	4,7	797

Table III

δ (mm)	l (m)	b (mm)	G (g)
0,015	24,7	20	59
0,030	34,6	14,3	118
0,05	45,0	11	148
0,10	63,0	8	400
0,20	88,0	5,7	800
0,40	124	4,0	1600
1,0	202	2,5	4040

Table IV

δ (mm)	l (m)	b (mm)	G (g)
0,015	99	4,8	19,0
0,030	140	3,5	39,7
0,050	194	2,5	65,0
0,10	273	1,9	132
0,20	385	1,3	270

Tables V and VI show examples of physical dimensions of heating elements in accordance with the present invention operating under a low potential of 12 V for dissipating a power rating of 1 KWatt for heating an air based medium at an ambient temperature of about 20° while maintaining a surface temperature of about 70–80°. Table V gives some physical dimensions in the case of transformer steel with a specific resistance 0.6 Ohm•mm^2/m and Table VI shows examples of physical dimensions for aluminum with a specific resistance of 0.035 Ohm•mm^2/m. Both are for temperatures within the range of 70–80°C.

Table V

δ (mm)	l (m)	b (mm)	G (g)
0,015	1,33	370	59
0,030	1,87	262	117
0,050	2,4	201	192
0,10	3,4	142	386
0,20	4,8	100,7	773

Table VI

δ (mm)	l (m)	b (mm)	G (g)
0,015	5,5	89	20,0
0,030	7,75	63	39,5
0,050	10,1	48	65,0
0,10	14,2	34	130
0,20	20,0	24	259

Further features of electric heating devices in accordance with the teachings of the present invention as will become apparent hereinbelow are as follows: First, the surface temperature of the electric heating devices is generally low depending on the particular application at hand, thereby considerably lowering and at times totally eliminating the risks of burns, fires, and the like. Second, the current passing through the electric heating devices is generally quite high but is not a potential source of electric shocks which are due to high voltage and not high current. Third, low operating voltages can be used to energize the electric heating devices, thereby obviating the need for an earth connection, insulation, and the like. And lastly, the weight of the electric heating devices is generally quite low and, as evidenced in the above Tables, typically below 1 Kg.

Turning now to Fig. 2, it depicts an electric heating device, generally designated **20**, for providing a comfortable heated air convection around a bed. The specifications of the electric heating device **20** may include, for example, a power rating of about 1 KWatt and an operating voltage of about 6V delivered by a step–down transformer **22** from a 220 V ac mains supply.

In this case, the electric heating device **20** may, for example, be implemented as a heating element **24** made of transformer steel bands **25** and **26** having a specific resistivity ρ of about 0.6 Ohm•mm²/m, a length l of about 1.7 m, a width b of about 280 mm and a thickness δ of about 0.05 mm. The electric circuit is formed by leads **28** connected one to each of bands **25** and **26** through contacts **29** and **30**, respectively, and a shorting lead or band connecting the two bands **25** and **26** at their rear end (the latter not shown). The current flowing through the bands is about 165 Amps and although leads **28** are represented here as thin leads and the contacts **29** and **30** are shown as point contacts, it will be appreciated that given the magnitude of the current, heavy leads and very low resistance contact have to be provided. Typically, the surface temperature of the bands **25** and **26** is about 70–80°. It should be noted that in accordance with the relations (1) and (2) hereinabove, the values obtained for the length l is $l \geq 1$ m and the width b is $b \geq 170$ mm, respectively.

Fig. 3 depicts an electric heating device, generally designated **36**, for heating a children's bedroom. The specifications of the electric heating device **36** may include a power rating of about 1 KWatt and an operating voltage of about 6V delivered by a step–down transformer **37** from a 220 V ac mains supply.

In this case, the electric heating device **36** includes a heating element, implemented in a picutre **38**. The heating element (not shown) may have the form of an aluminum band having a specific resistivity ρ of about 0.035 Ohm•mm²/m, a length l of about 5.0 m, a width b of about 80 mm and a thickness δ of about 0.015 mm. The band can be provided as an

array of continuously connected horizontal segments or continuously connected vertical segments forming a rectangular waveform like shape and the like. Typically, the surface temperature of the electric heating device **36** is in the range of about 50–60°C. It should be noted that in accordance with the relations (1) and (2) hereinabove, the values obtained for the length l is $l \geq 5$ m and the width b is $b \geq 70$ mm, respectively. Picture **38** which can be hung on a wall. In practice, the band is preferably insulated such as by being sandwiched between two polyethylene films and mounted on an aluminum sheet having a wooden or plastic frame.

Fig. 4 depicts an electric heating device, generally designated **40**, for heating a lounge. This heating device is implemented as a cylindrical element **42** on a pole **44** of a free standing lamp **46**. The specifications of the electric heating device **40** may include, for example, a power rating of about 1 KWatt and an operating voltage from a 220 V ac mains supply.

In this example, the electric heating device **40** includes a heating element in the form of a transformer steel band which is enclosed within cylindrical heating device 42, having a specific resistivity ρ of about 0.6 Ohm•mm^2/m, a length l of about 38 m, a width b of about 10 mm and a thickness δ of about 0.05 mm. Typically, the surface temperature of the electric heating device **40** is in the range of about 70–80°C. It should be noted that in accordance with the relations (1) and (2) hereinabove, the values obtained for the length l is $l \geq 37.7$ m and the width b is $b \geq 9.4$ mm, respectively.

Device **40** is provided also with a three way switch **48** enabling operation of the electric heating device 42, the lamp **46**, or both.

Fig. 5 depicts an electric heating device, generally designated **50**, for heating a bathroom.. The specification of the electric heating device **50** may, for example, include a power rating of about 1.5 KWatt and an operating voltage of about 12 V, obtained through a step down transformer **52** from a 220 V ac mains supply. As shown, the electric heating device **50** comprises a heating element 54, formed from a band

which tracks three sides of a right angled rectangle, which is attached, e.g. by gluing, to the outside surface of a bath **56**. Element **54** is preferably covered by a water impermeable film, such as a polyethylene film. An electric current from transformer **52** is provided by leads **58** and similarly as in the embodiment shown in Fig. 2, the leads should be adapted to transfer the needed current (about 125 Amps) and the contacts of the leads with element **54** should be of a very low resistance.

The heating element **54** may, for example, be a stainless steel band having a specific resistivity ρ of about 0.75 Ohm•mm²/m, a total length l of abut 2.5 m, a width b of about 200 mm and a thickness δ of about 0.1 mm. Typically, the surface temperature of the electric heating element **54** is about 60–80°C. It should be noted that in accordance with the relations (1) and (2) hereinabove, the values obtained for the length l is $l \geq 2.5$ m and the width b is $b \geq 200$ mm, respectively.

Fig. 6 shows a heating device generally designated **60** implemented within the upper beam **62** of a window or door frame **64**. Heating device **60**, as can particularly be seen in Fig. 6B, includes a step down transformer **66**, receiving 220 V ac mains supply, a heating element **68** in the form of a band which tracks a reciprocating path along the length of beam **62**. An electric current to heating element **68** is provided through electric leads **70**. The heating element **68** is provided with a number of space retainers **72** made from an insulating material such as heat resistant plastic or a ceramic.

Heating element **64**, may for example, be a low alloy stainless steel band having a specific resistivity ρ of about 0.3 Ohm•mm²/m, a total length of about 1.5 m (i.e. 2x0.75 m), a width b of about 100 mm and a thickness δ of about 0.2 mm. The power rating is for example about 1 kW and the operating voltage is about 6 V. During operation, the heating element reaches a working temperature of about 70–80°C and a temperature on the external surface of beam **62** will thus be about 35°C.

Fig. 7 depicts an electric heating device, generally designated **80**, for heating food portions. The specifications of the electric heating device **80** include a power rating of about 1 KWatt and an operating voltage of about 6 V obtained via a step down transformer **82** from a 220 V ac mains supply.

In this case, the electric heating device **80** includes a heating element in the form of a stainless steel band having a specific resistivity ρ of about 0.75 Ohm•mm^2/m, a length l of about 0.8 m, a width b of about 90 mm and a thickness δ of about 0.2 mm. Typically, the surface temperature of the electric heating device **80** is in the range of about 140–160°C. It should be noted that in accordance with the relations (1) and (2) hereinabove, the values obtained for the length l is $l \geq 0.63$ m and the width b is $b \geq 63$ mm, respectively. As shown, the electric heating element of device **80** is best included as the top surface **83** of the oven type device **84** with the bottom wall **86** made of an electrically non–conductive material. The heating of top surface **82** heats the enclosed volume including the one or more food portions **88**.

Fig. 8 shows a cooking assembly with interchangeable heating elements for a variety of cooking applications. Assembly **90**, shown in Fig. 8A, comprises a plate **92** made from an electrically insulating material, a step down transformer **94**, a heating element **96** and an electric contact assembly **98**. In the embodiment shown, cooking element **96** has a trapezoidal cross–sectional shape with the bottom side removed, as can best be seen in Fig. 8B. As can further be seen, heating element **96** defines an enclosure **100** containing food items **102**, specifically food items to be baked.

The specifications of this heating device may include a power rating of about 1 kW and an operational voltage of about 3 V. Element **96** typically made of stainless steel having a specific resistivity ρ of about 0.75 Ohm•mm^2/m having a total length (from one end to the other end of the looped path tracked thereby) of about 3 cm, a width (including two sides

and upper walls of the element) of about 130 mm and a thickness of about 0.2 mm. During operation, the element has an output temperature of about 60–250°C which heats up space **100** and brings to cooking of food items **102**.

Contact assembly **98** which is shown in cross-section in Fig. 8C allows tight electric contact on the one hand and interchangeability on the other hand. Element **96** has two contact plates **104** and **106**. Contact assembly **98** comprises a clamping plate **108** which is pushed downwards by means of a clamping lever **110** which by the intermediary of insulator sheet **112** clamps plates **104** and **106** to plates **116** and **118**, respectively, which are electrically connected to the output of transformer **94**.

Fig. 8D shows system **90** incorporating a different heating element assembly **120**. Assembly **120** comprises a heating element **122** fashioned as a band reciprocating between two members **124** and **126** made from an insulating material. Element **122** may typically be made of stainless steel with a specific resistivity of ρ of about 0.75 Ohm•mm^2/m, a total length l of about 0.6 m, a width b of about 80 mm and a thickness δ of about 0.2 mm.

The specification of this element include a power rating of about 0.5 kW.

The working temperature achieved in this element is typically about 260°C and suitable for frying food items such as, for example, meat. As can be seen in the cross-sectional view shown in Fig. 8E, food items **128** which may for example be steaks placed within different turns of element **122**, may then be fired simultaneously from both sides.

Fig. 8F shows the electric contact members of element **126** which includes two metal plates **130** and **132** integral with the upper and the lower turn of the element, respectively. Generally, the power, and hence the temperature of the heating element of assembly **90** may be controlled by control means (not shown) adapted to change the output voltage.

Figs. 9A and 9B depict an electric heating device, generally designated **160**, for therapeutic heating purposes. The specifications of the electric heating device **160** typically includes a power rating of about 100 Watt and an operating voltage of about 6 V achieved via a step down transformer **162** from a 220 V ac mains supply.

Device **160** includes a heating element **164** packaged within a plastic envelope **166** together with a quantity of a water–based gel and having ends connected to external sockets **168**. The element has the form of a band, e.g. made of copper, having a specific resistivity ρ of about 0.022 Ohm•mm^2/m, a length l of about 0.6 m, a width b of about 11 mm and a thickness δ of about 0.015 mm. It should be noted that in accordance with the relations (1) and (2) hereinabove, the values obtained for the length l is $l \geq 0.5$ m and the width b is $b \geq 7$ mm, respectively. Typically, the surface temperature of the envelope **166** is about 40–45°C. As can be seen in Fig. 9B, the device may be attached to an arm or to another body part, as needed, for heating of the arm or the other body part. The attachment may be by rubber strings, bands, etc., as generally known *per se* (not shown in Fig. 9A).

A therapeutic device in accordance with another embodiment of the invention is shown in Fig. 10. This device generally designated **170** comprises a cloth based matrix **172** and a heating element **174** embedded therein. The heating element, shown herein as a line (which is for ease of illustration only) is a band which is made to track a torturous sinosoidal path throughout the surface of the device. The device comprises fastening straps **176**, which as can be inferred from Fig. 10B, attach by means of a Velcro™ type attachment to the external surface of the device, forming a therapeutic bandage around an upper leg portion of an individual. The specifications of the electric heating device typically include power rating of about 120 W and an operating voltage of about 6 V. The heating element is typically made of stainless steel having a specific resistivity ρ of about 0.75 Ohm•mm^2/m, a total length l of 1 m, a width b of about 16 mm

and a thickness ρ of about 0.1 mm. The output temperature of the heating element is controllable up to a temperature of about 50°C by changing the output voltage.

Other therapeutic devices in accordance with the invention are shown in Figs. 11–15. The device in Fig. 11 is intended for heating of an elbow, that shown in Fig. 12 for heating an individual's back, and those in Figs. 13 and 14 for heating the hand or a foot, respectively. The device in accordance with the embodiment of Figs. 13 and 14 can also be designed for use by individuals exposed to extreme cold, such as soldiers, mountain climbers, skiers, etc.

Reference is now made to Fig. 15 which shows another embodiment of a domestic heating appliance of the invention, which achieves heating by air convection. The device generally designed 220 of this embodiment consists of a frame 222 which has upper and lower frame sections 224 and 226, respectively, which have a crescent–like shape. The heating device comprises a heating element 228 which is an elongated band which criss–crosses between the upper and the lower frame sections 224 and 226 to form a grill–like structure. The ends of the heating element are connected to an electric power source typically a low voltage source within the range of 6–24 volts (not shown). A unique feature of this device is that it is lightweight and portable. The heating element 228 may typically have a working temperature within the range of 60–80°C.

While the invention has been described with respect to a limited number of embodiments, it will be appreciated that many variations, modifications and other applications of the invention may be made.

CLAIMS:

1. A heating device having an output surface through which heat is dissipated and comprising a heating element operating under an electric potential U for dissipating heat power rating W, the heating element being characterized in that:

(i) the heating element, made of an electric conductive material of a specific resistivity ρ is substantially flat and has a substantially rectangular cross section, the heating element having a length l along which the electric potential U falls, a width b and a thickness δ so as to define at least one major surface of the heating element having an area bl; and

(ii) the length l, the width b and the thickness δ of the heating element being such so as to allow generation of the heat power rating W under the electric potential U and the current I, where $W = UI$, by satisfying the following relations (1) and (2):

$$l \geq k_1 U \sqrt{\frac{\delta}{\rho}} \tag{1}$$

$$b \geq k_2 I \sqrt{\frac{\rho}{\delta}} \tag{2}$$

wherein k_1 is 200 and k_2 is 0.2 with the units of length l being meters, the units of the width b and the thickness δ being millimeters, and the units of the specific resistivity ρ of the heating element being Ohm•mm²/m.

2. A device according to Claim 1, for use in heating air at room temperature to a temperature of 100°C or more, or to heat a water based medium consisting of at least 50% water at an initial room temperature, to

a temperature up to about 50°C, or in a k_1 is within the range of 200–600 and k_2 is within the range of 0.2–0.6.

3. A device according to Claim 1, for use in heating air at room temperature to a temperature up to about 90° or less, wherein k_1 is above 600 and k_2 about 0.6.

4. A heating device comprising a heating element incorporated in a structural component in a stationary object.

5. A stationary object such as furniture or the like, comprising a heating element as an added component attached to or embedded with said object, the heating element having a working temperature of 8° or less.

6. A food heating device, comprising a flat metal body which is either in contact with the food or which is in proximity with the food without any object between it and the food, said metal body serving as a heating element being connected to a power source for passing heating electric current therethough.

7. A cooking device according to Claim 6, for heating of liquid food, comprising a metal vessel for holding the food having metal walls serving as heating elements, and comprising a power source for passing low voltage, high power electric current therethrough, thereby heating the liquid food contained therein.

8. A device according to Claim 6, for heating solid food items, in which the solid food items are placed in direct contact with a metal plate, said metal plate serving also as a heating element and being connected to an electric power source for passing a heating electric current therethrough.

9. A device according to Claim 6, for heating food by means of heat irradiation on to the food, comprising a food–containing enclosure having one or more metal walls, at least one of said metal walls serving as a heating element to heat said enclosure and being connected to a power source for passing a heating electric current therethrough.

10. A heating device to be worn or held on a body part for heating of that body part, comprising a matrix containing a heating element as defined in Claim 1.

11. A device according to Claim 10, wherein said matrix is a cloth or a cloth based matrix.

12. A device according to Claim 10, comprising a liquid or gel–containing enclosure having fiber walls with the heating elements contained therein.

13. A method for designing a heating element for implementing into a heating device for a predetermiend application, comprisng the steps of:

(a) specifying a desired power rating W and a range of operating potential U of the heating element in accordance with the predetermined application;

(b) specifying a list of at least one electrically conductive material in which the heating element can be formed in accordance with said application;

(c) specifying at least one of the length and the width of the heating element in accordance with said application;

(d) specifying the minimum thickness of the heating element in accordance with said application;

(e) specifying a desired working temperature of the heating element to suit said application;

(f) determining:

(i) a material from which the heating element is formed from amongst said list;

(ii) a thickness of the heating element which is at least equal to the minimum thickness, and

(iii) the other of the length, width and thickness of the heating element, so as to satisfy the following relationships:

$$l \geq k_1 \, U\sqrt{\frac{\delta}{\rho}} \tag{1}$$

$$b \geq k_2 I\sqrt{\frac{\rho}{\delta}} \tag{2}$$

wherein the dimensions of l, b, U, I, δ and ρ are as given above and k_1 and k_2 have the above values.

(g) verifying that the actual achieved working temperature is identical to the desired working temperature; and if different

(h) repeating steps (f) and (g) for at least one of different materials, thicknesses or the other of the length and the width, until the actual working temperature matches said desired temperature.

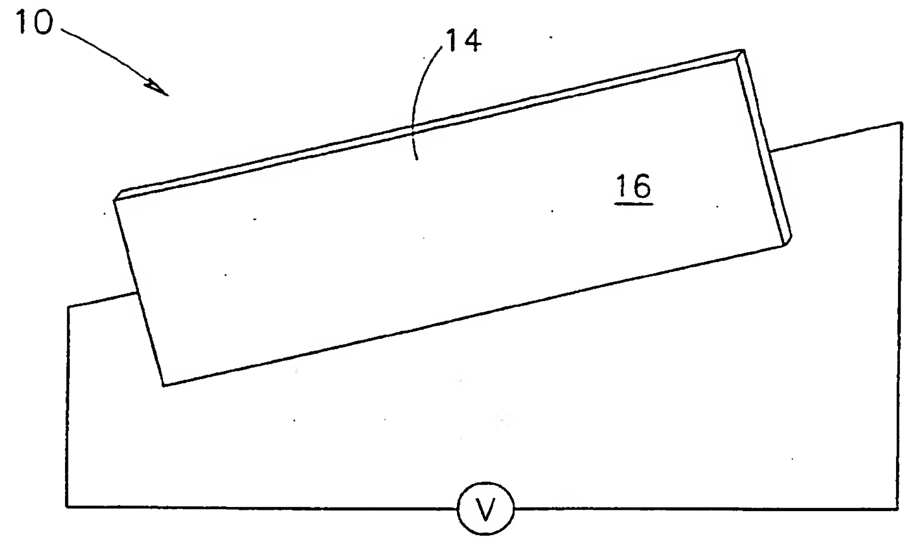


FIG. 1

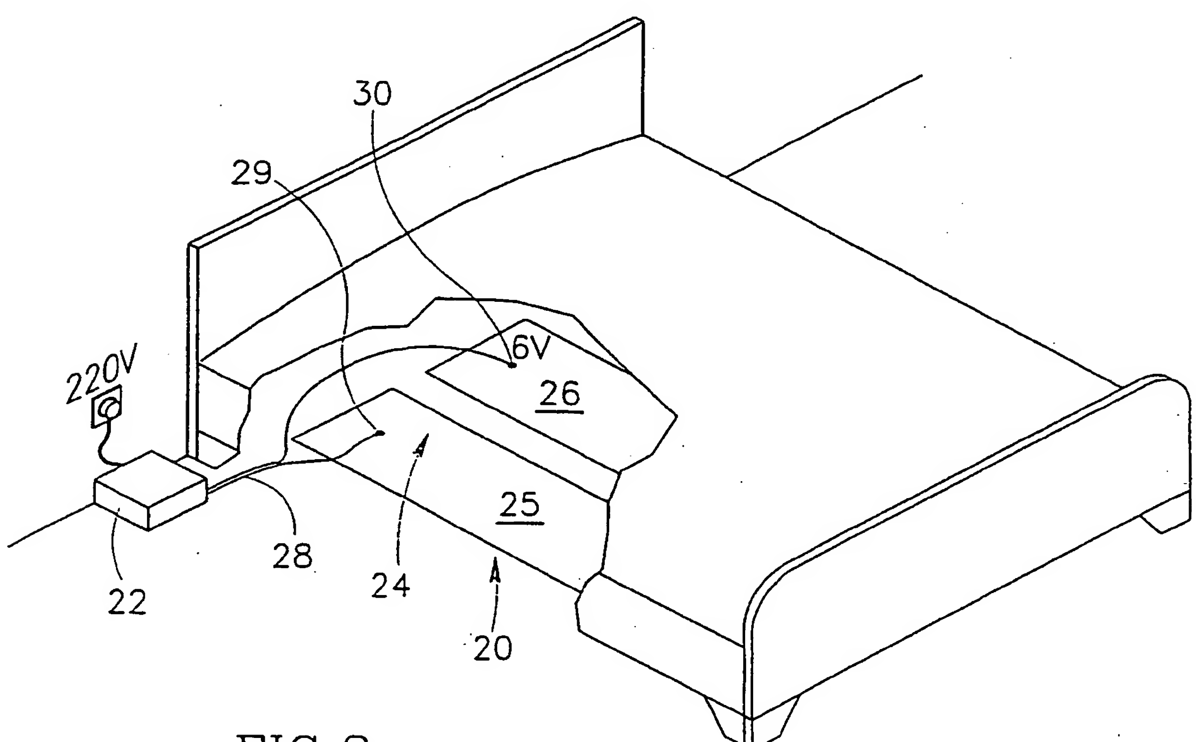


FIG. 2

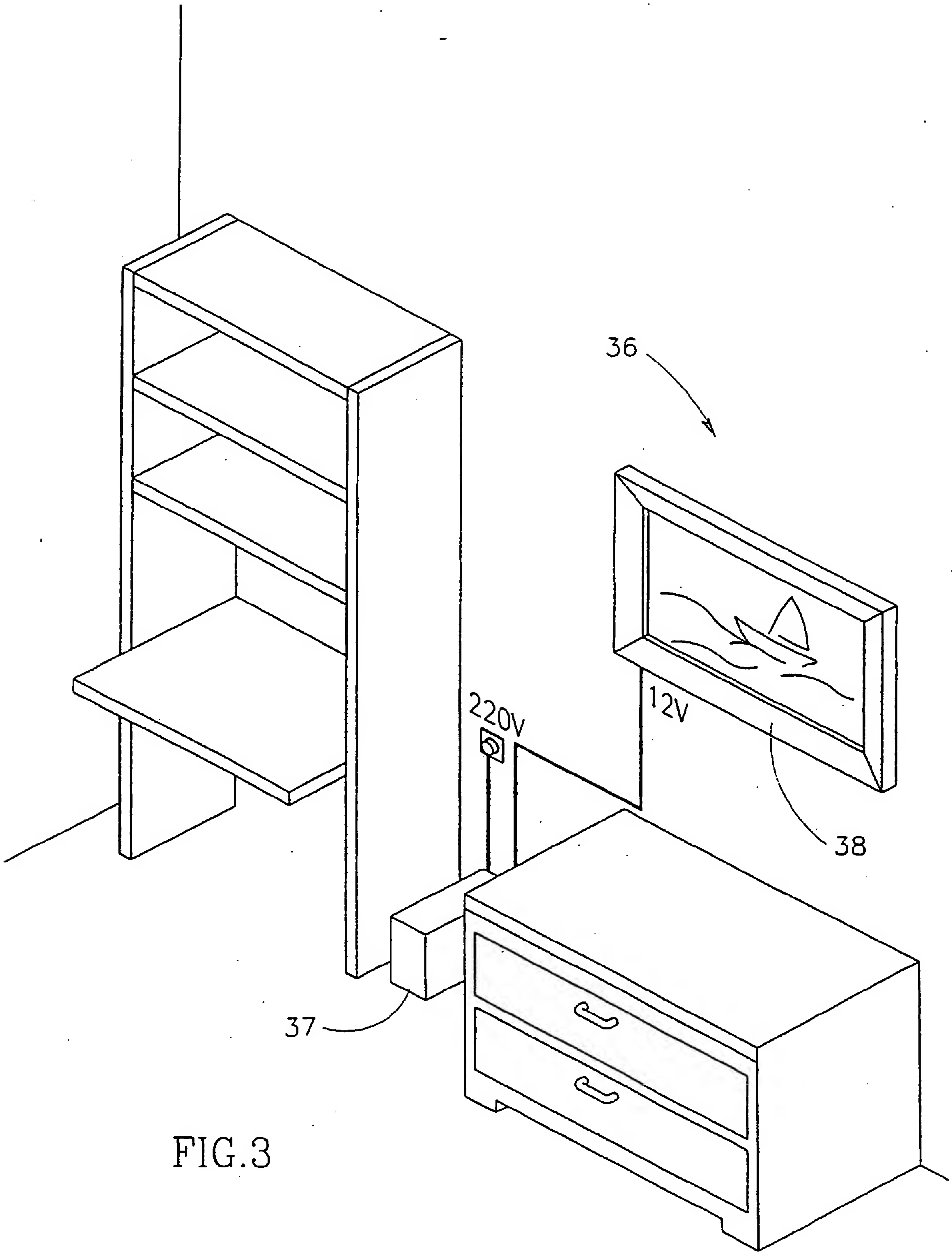


FIG.3

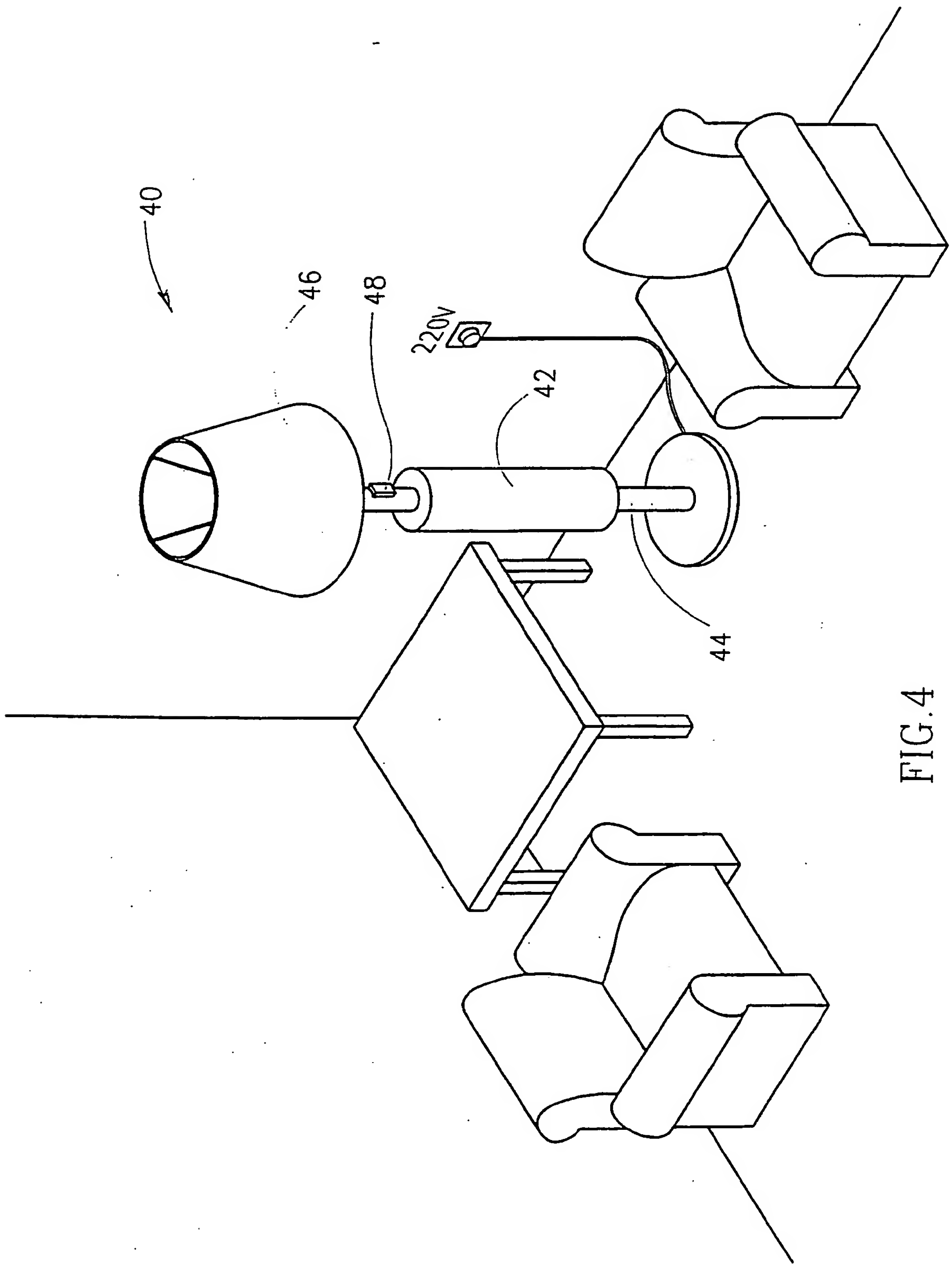


FIG.4

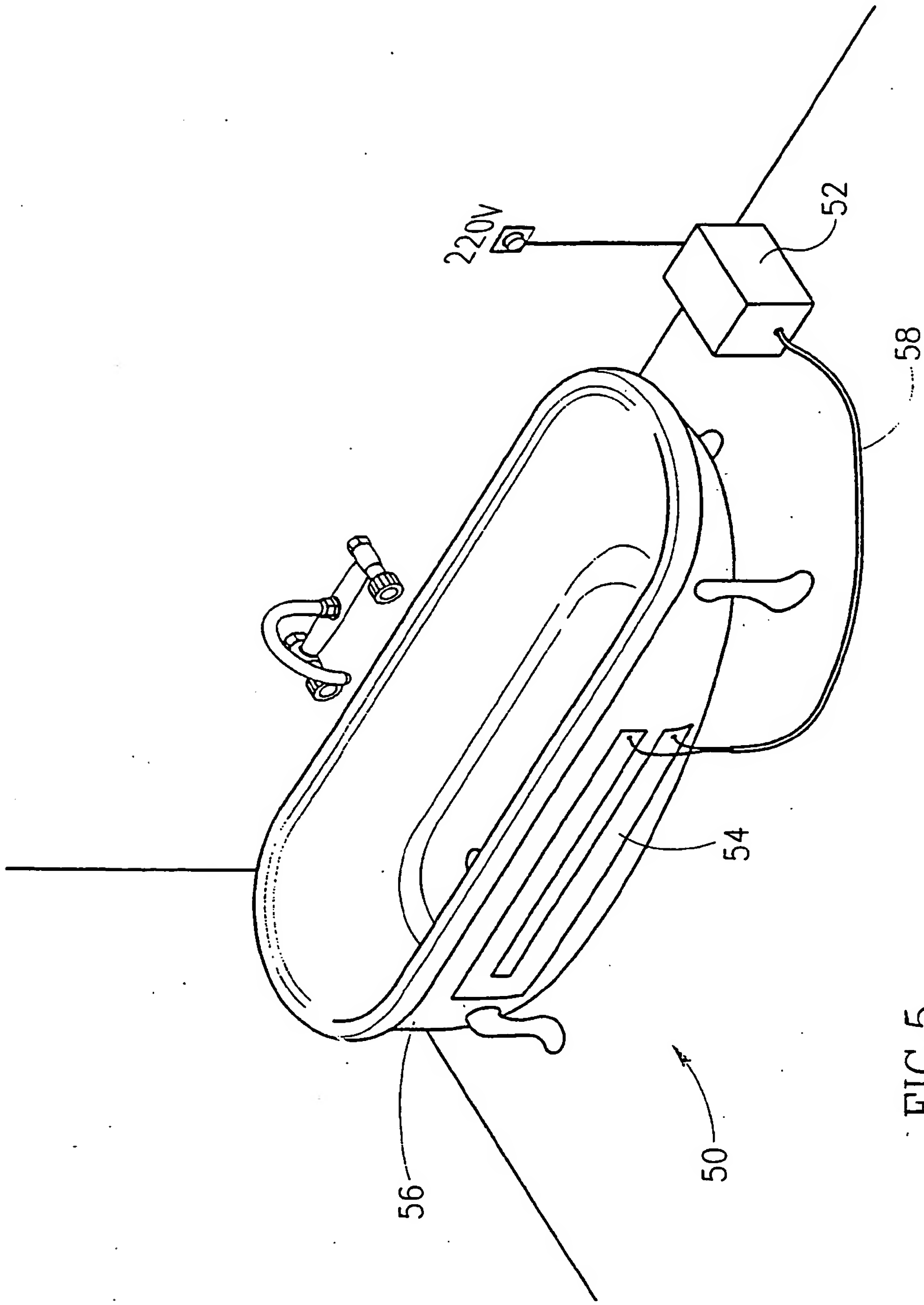


FIG.5

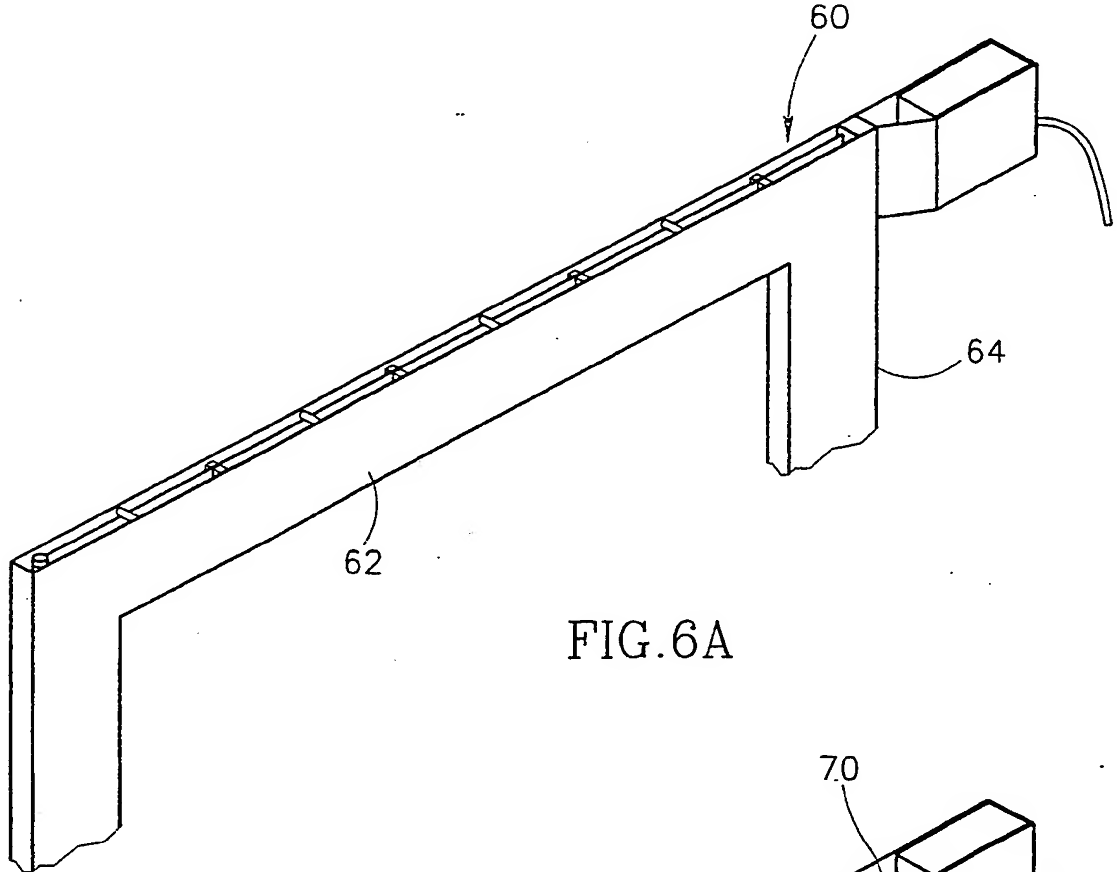


FIG.6A

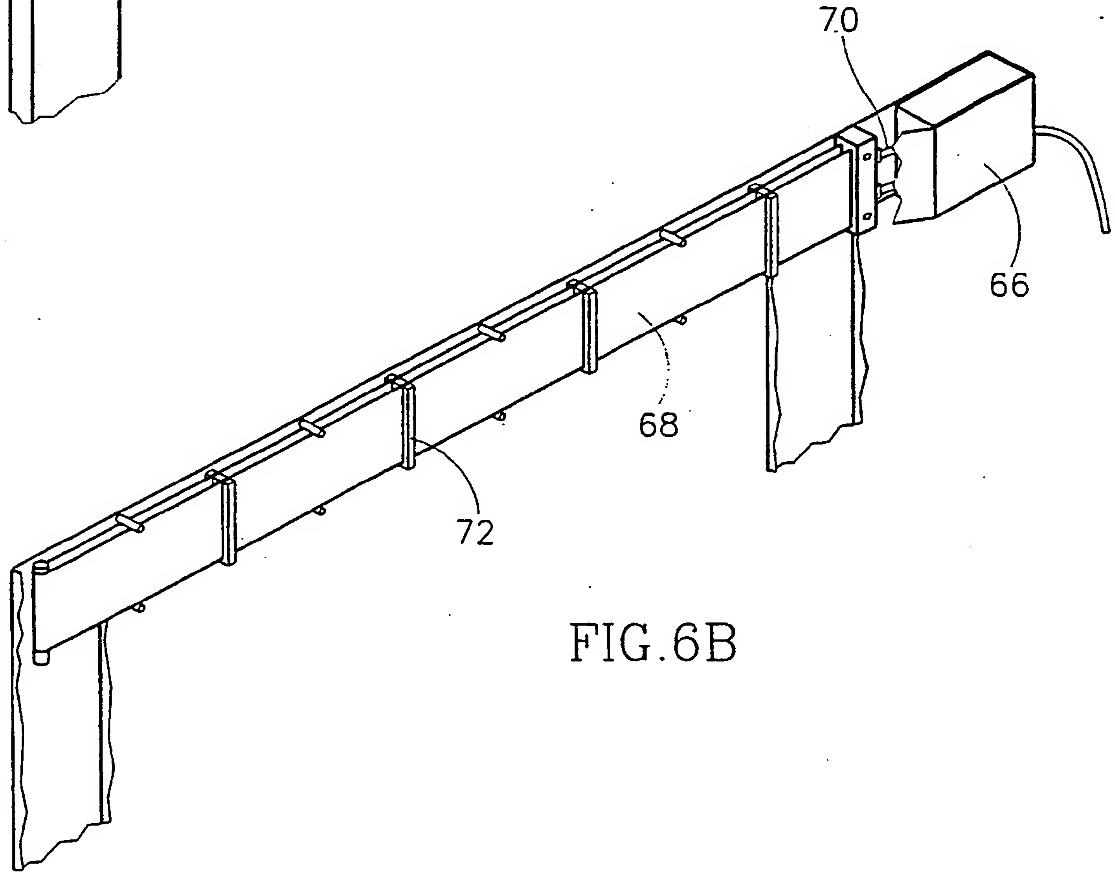


FIG.6B

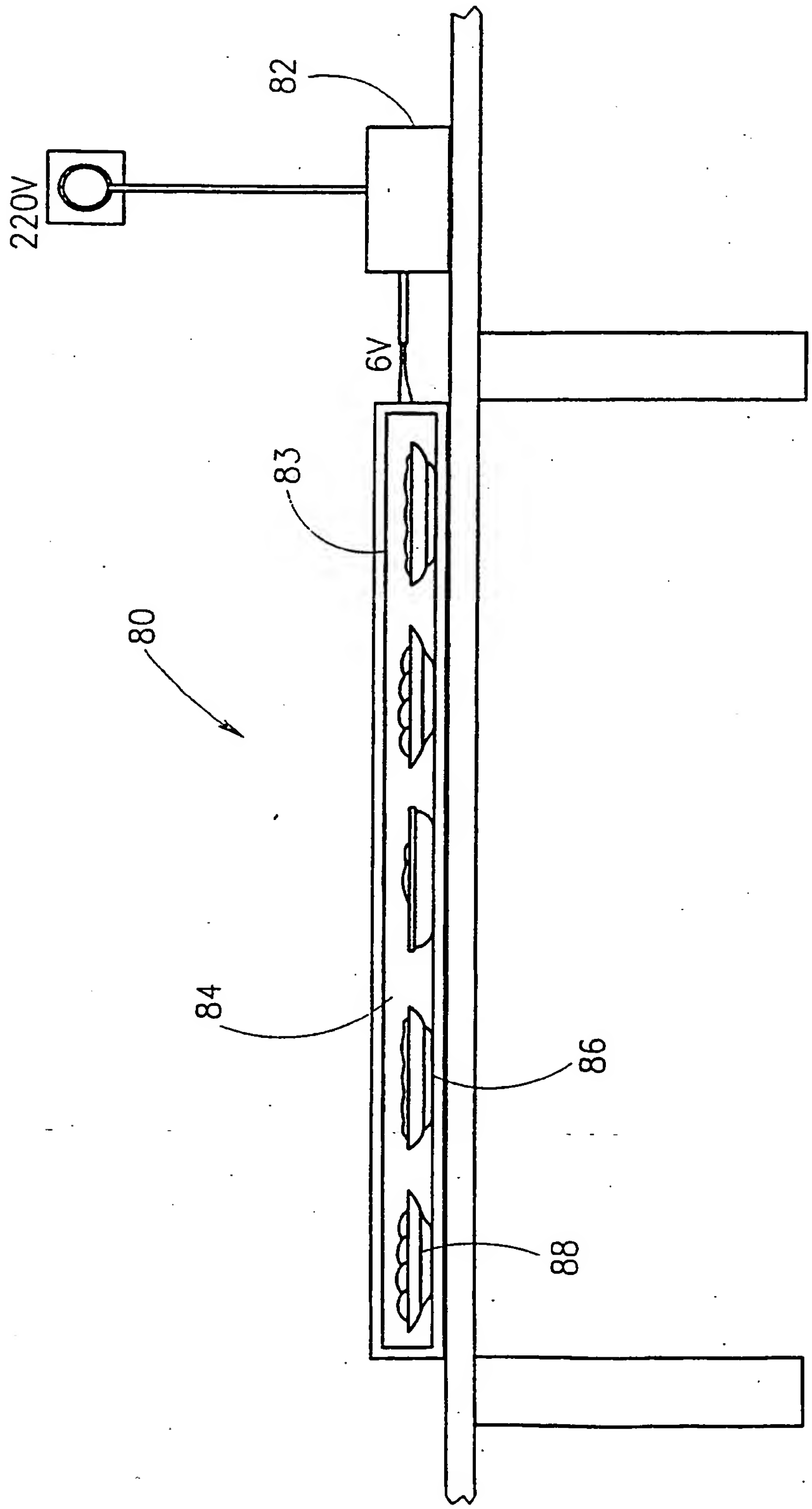


FIG.7

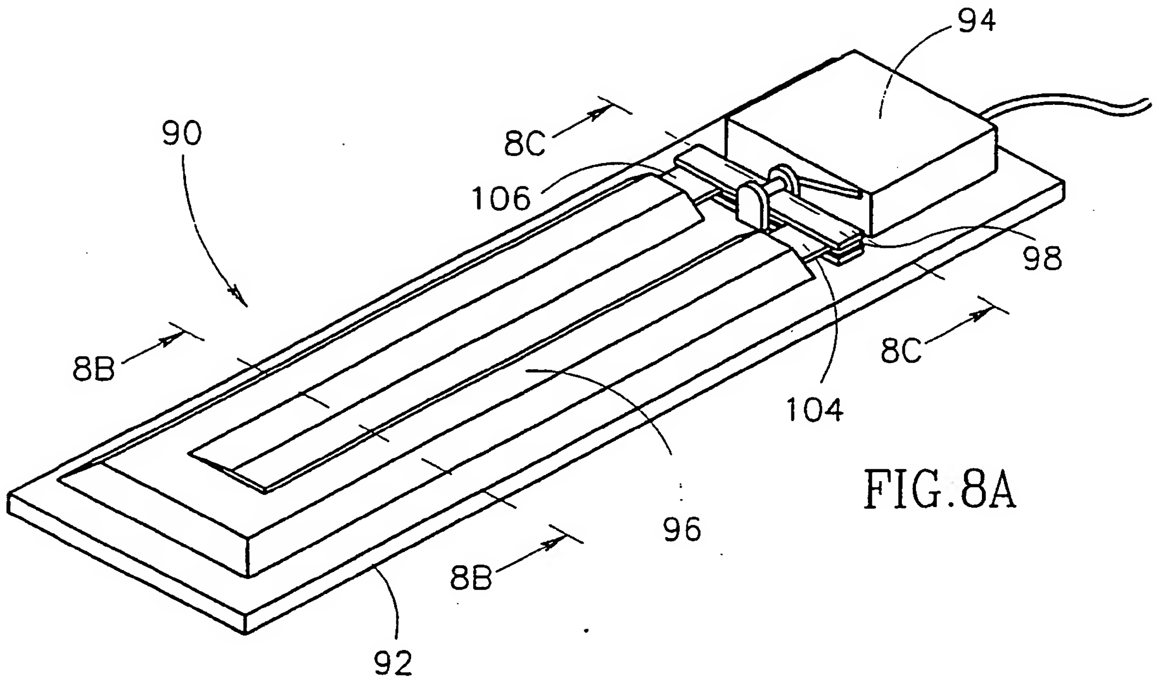


FIG.8A

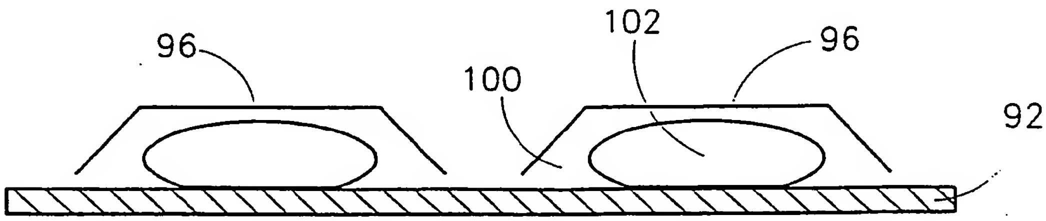


FIG.8B

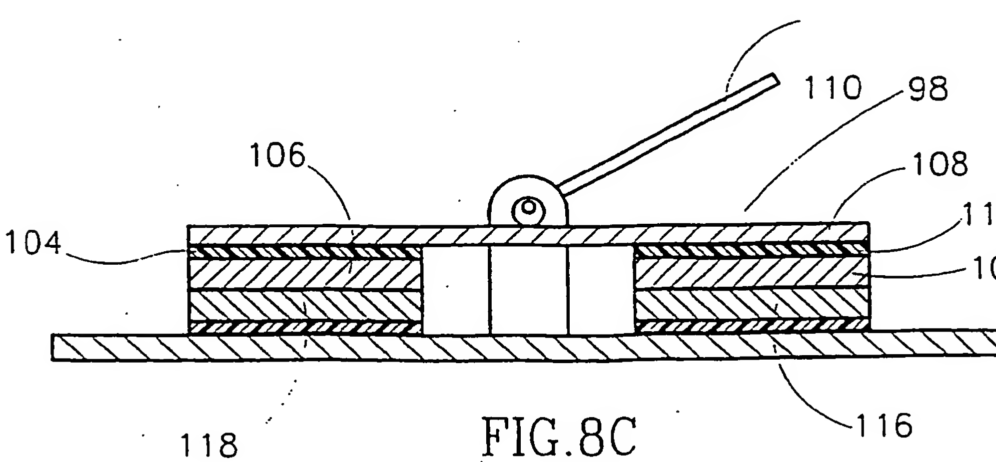


FIG.8C

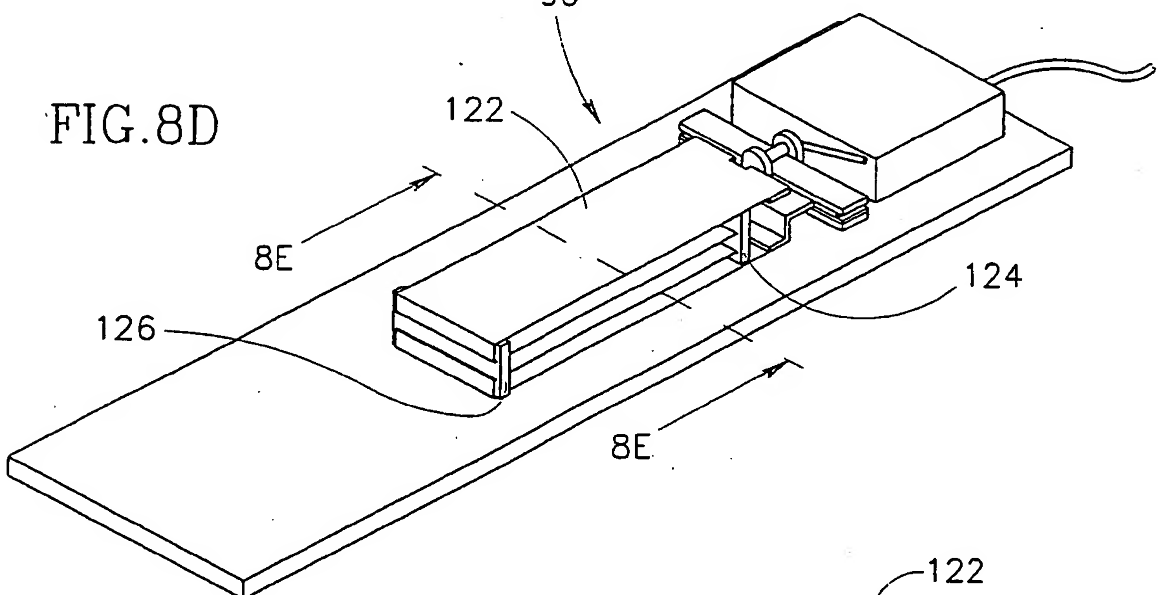


FIG.8D

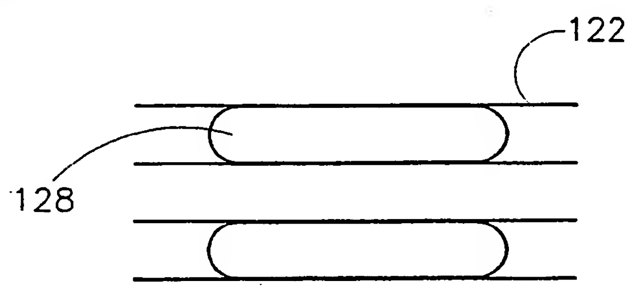


FIG.8E

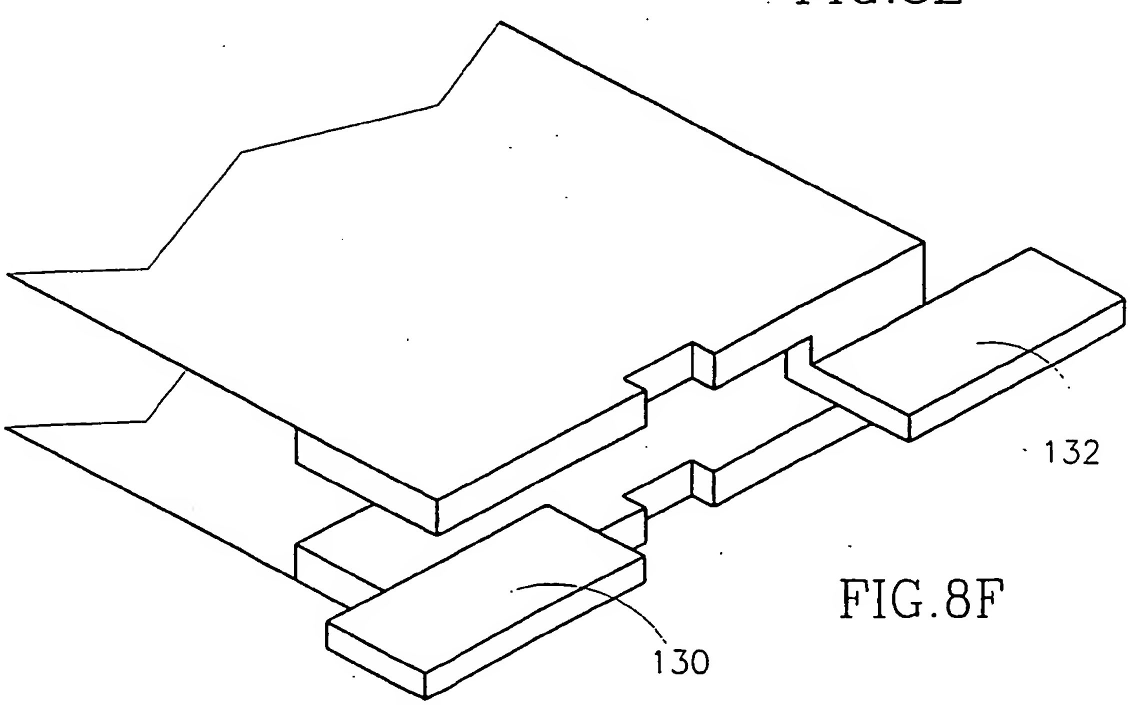


FIG.8F

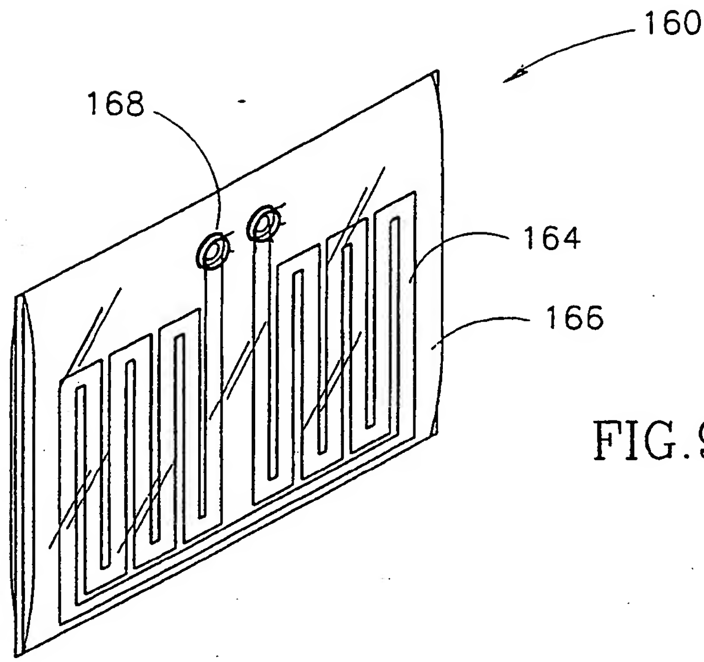
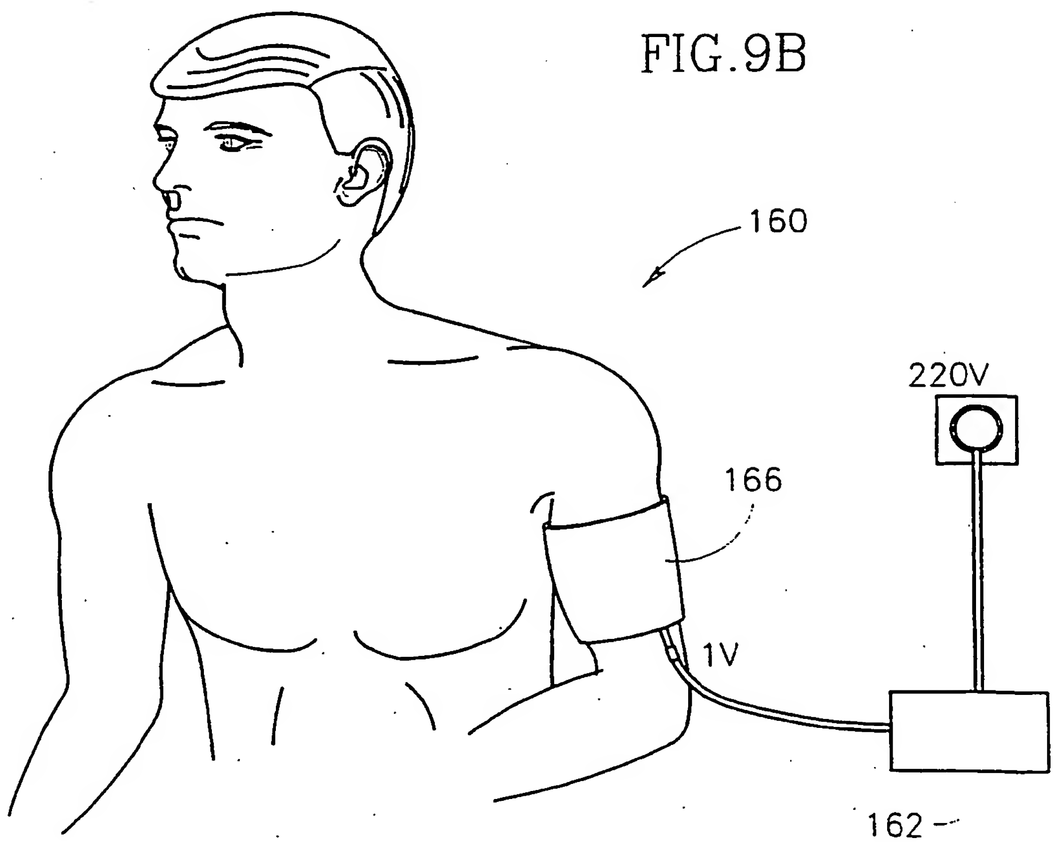


FIG.9A

FIG.9B



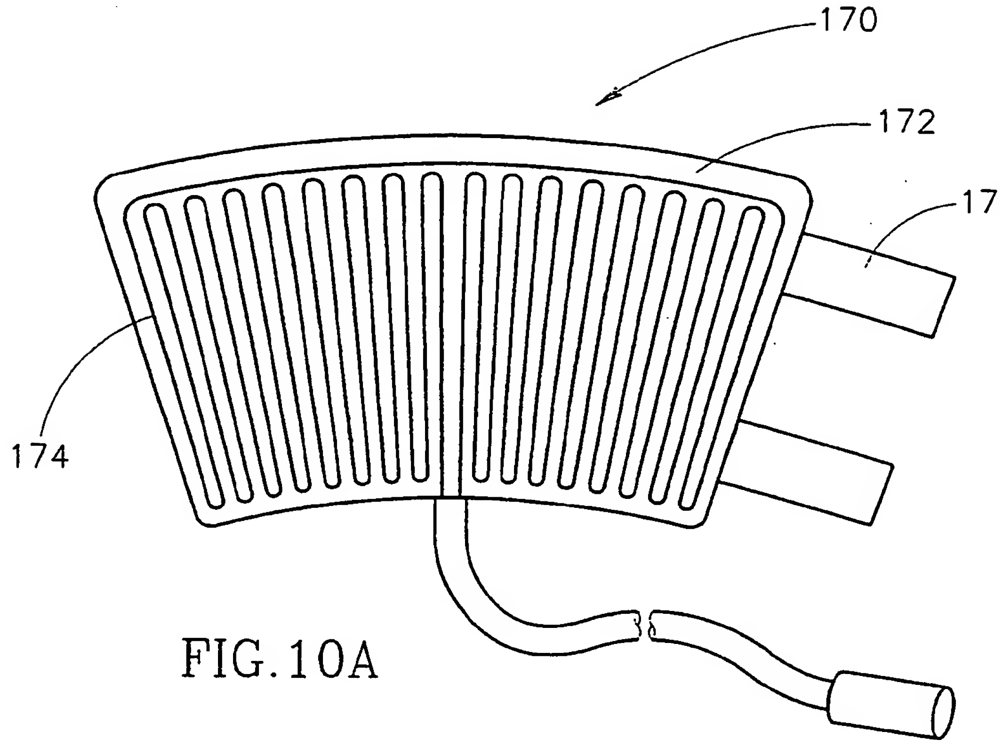


FIG.10A

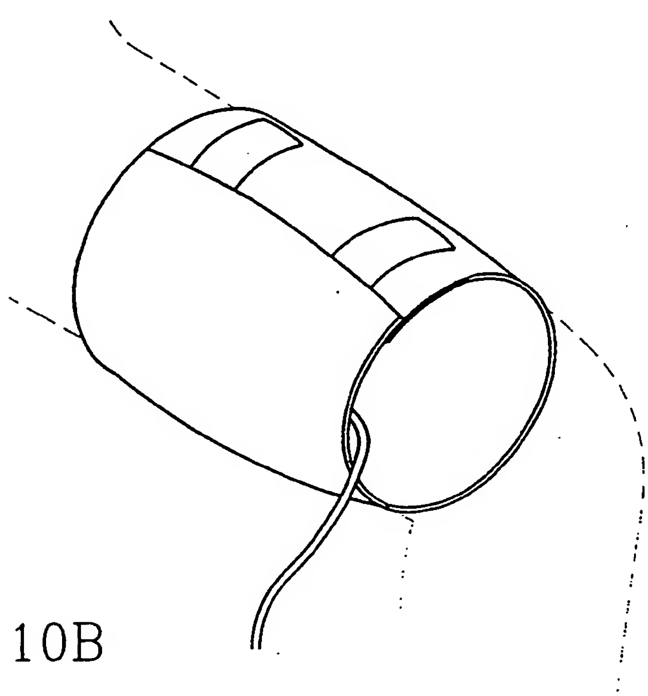


FIG.10B

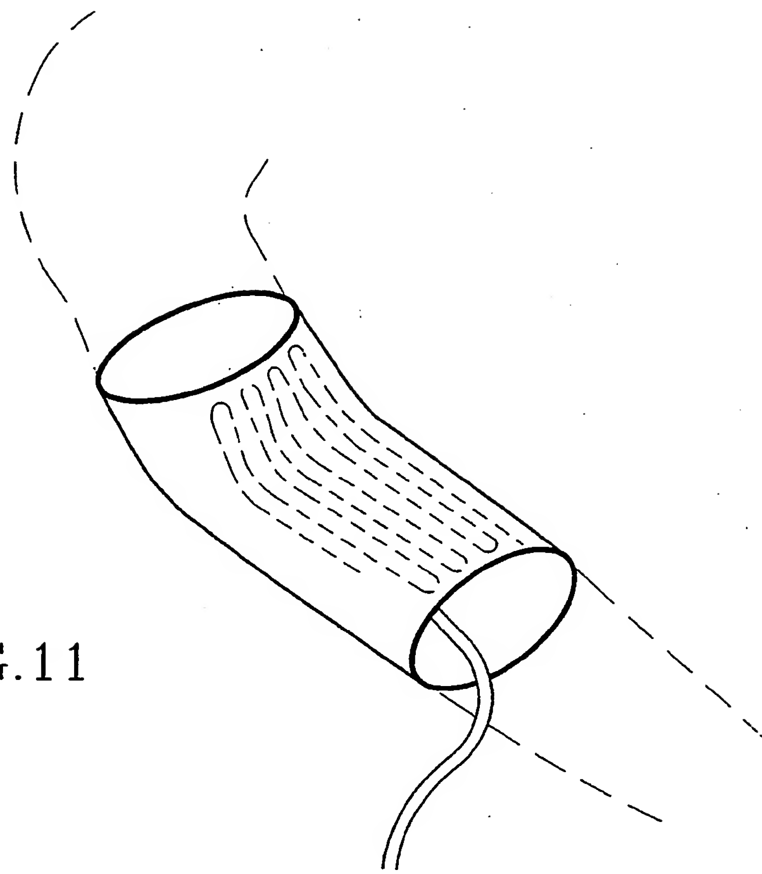


FIG.11

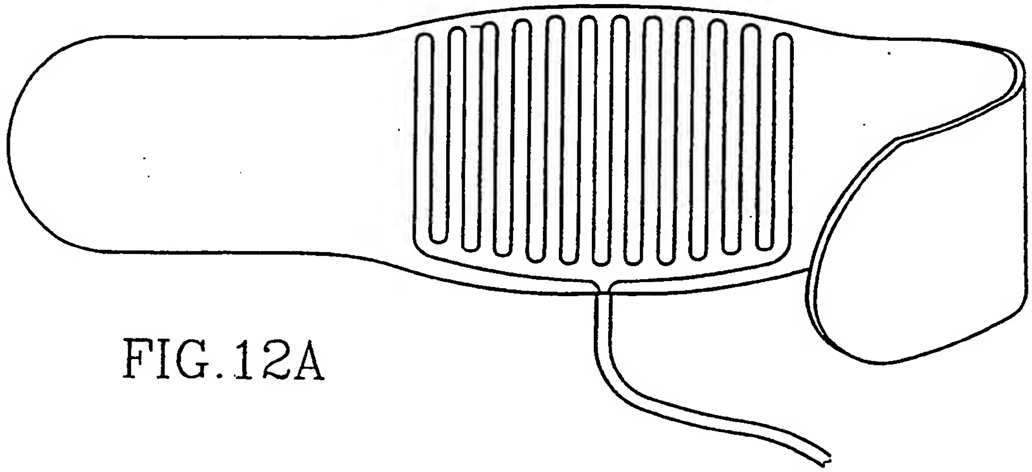


FIG.12A

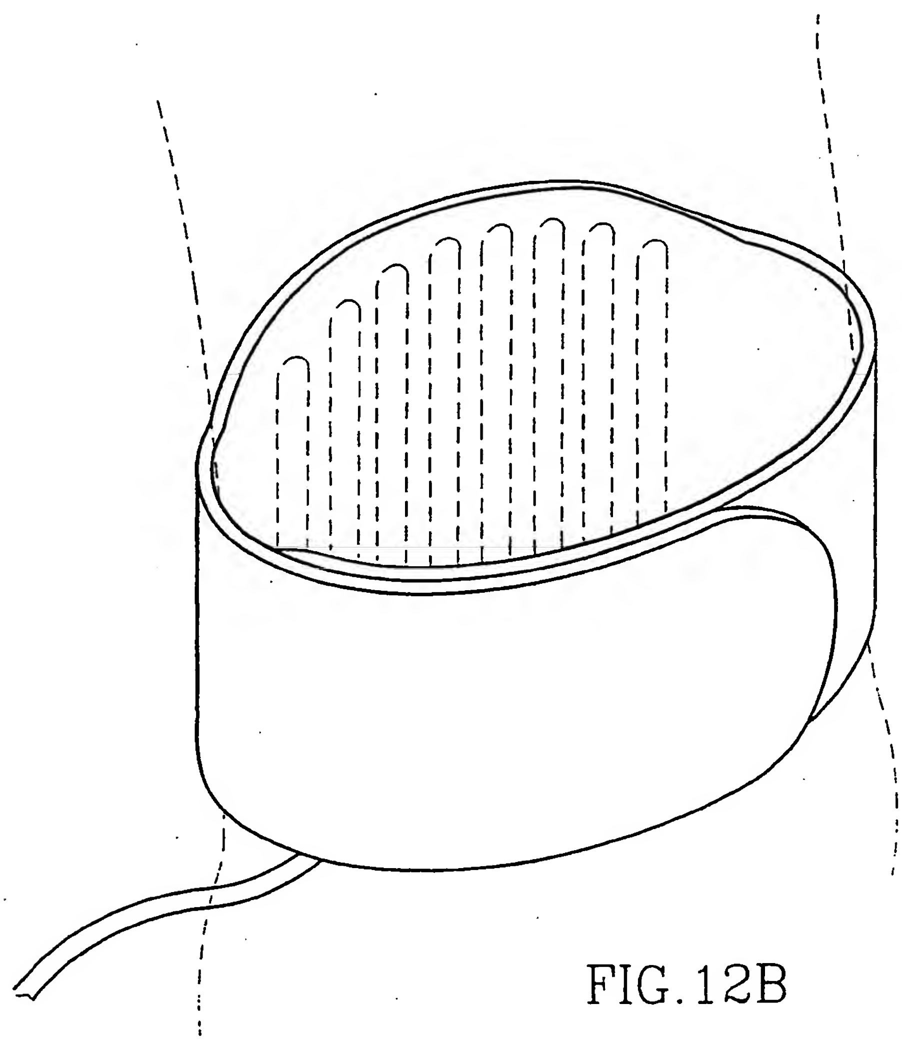


FIG.12B

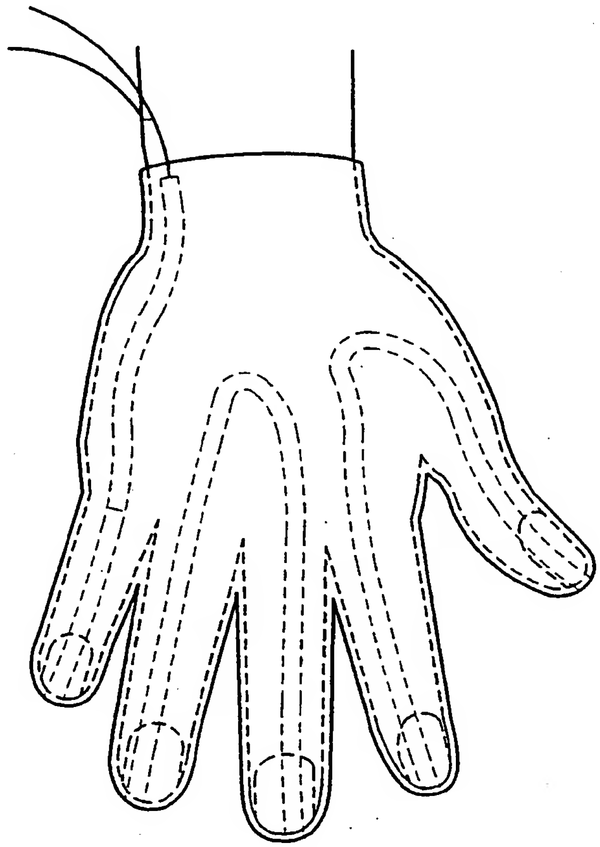


FIG.13

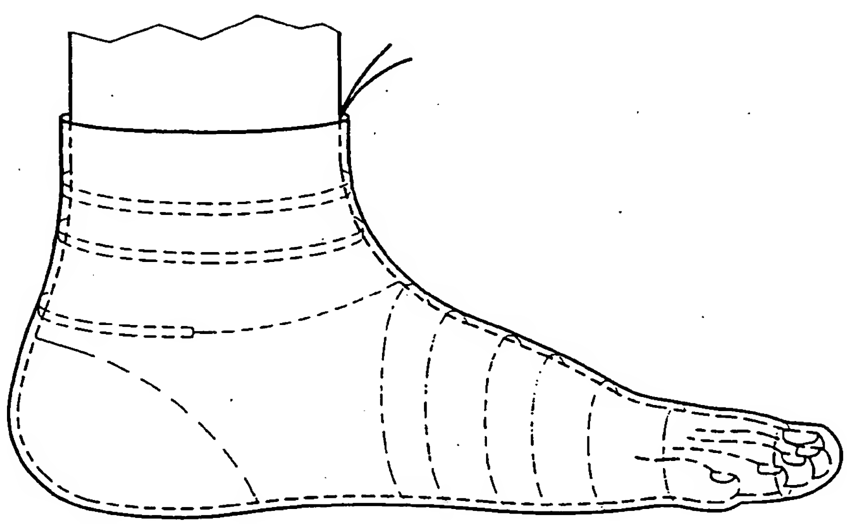


FIG.14

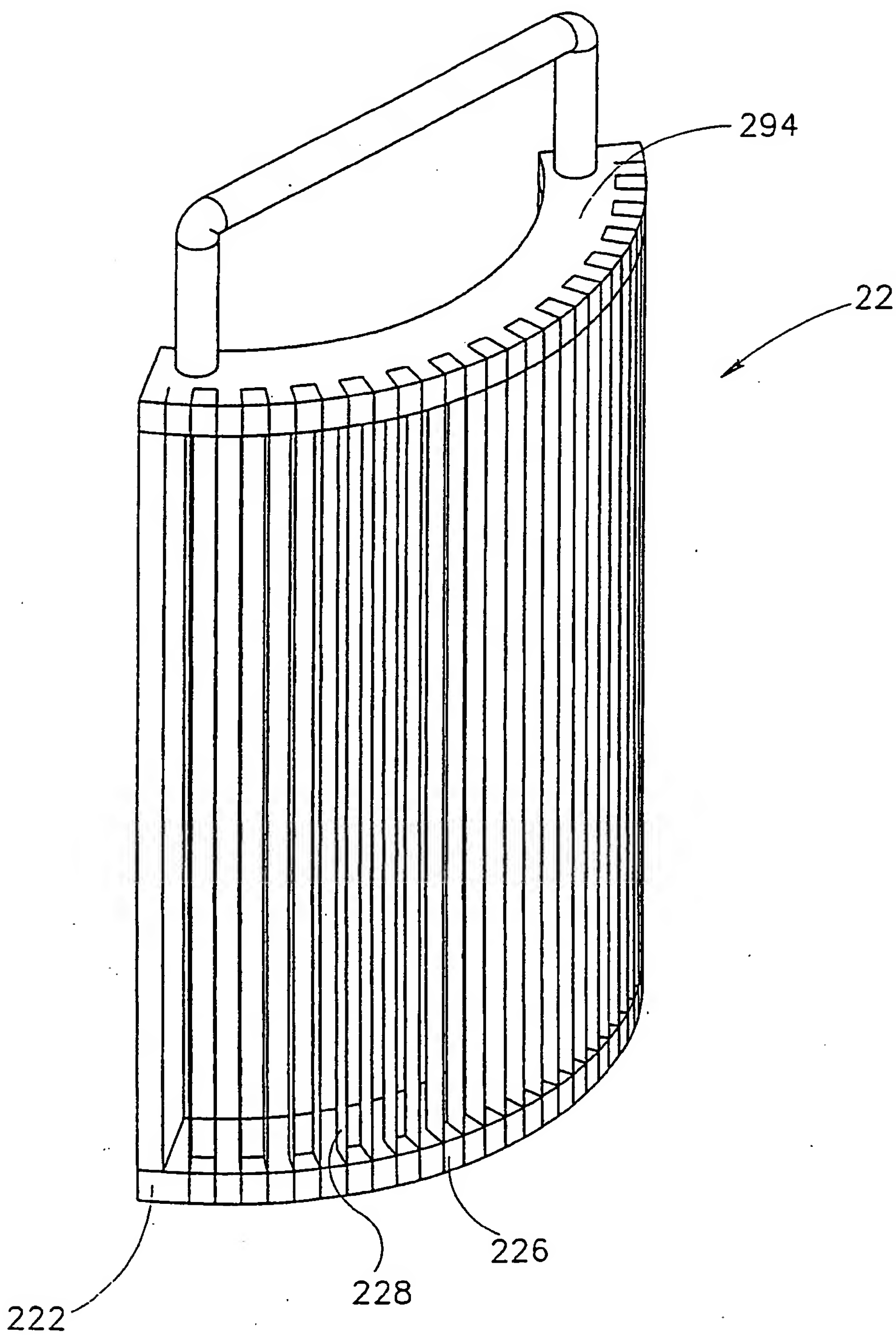


FIG.15

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IL 96/00096

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H05B3/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 357 945 (BUCHTAL GMBH) 14 March 1990 see column 5, line 3 - column 6, line 3; figures 1,2	4
A		5

X	DE,A,25 05 395 (SACHS SYSTEMTECHNIK GMBH) 19 August 1976 see page 9, line 6 - page 10, line 9; figures 1-3	6,8
A		7

A	GB,A,1 088 543 (IMPERIAL CHEMICAL INDUSTRIES) 25 October 1967 see page 1, line 29 - page 2, line 110	1-3,10, 11,13

	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

1 Date of the actual completion of the international search: 18 December 1996

Date of mailing of the international search report: 10. 01. 97

Name and mailing address of the ISA:
European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax (+31-70) 340-3016

Authorized officer: Albertsson, E

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IL 96/00096

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP,A,0 054 160 (MOULINEX SA) 23 June 1982 see page 1, line 22 - page 4, line 5; figures 1-5 ---	9
A	WO,A,87 04902 (FINNAH GMBH) 27 August 1987 ---	
A	US,A,3 737 624 (ELLENBERGER S) 5 June 1973 ---	
A	EP,A,0 609 088 (MITSUI TOATSU CHEMICALS) 3 August 1994 ---	
A	DE,A,34 18 612 (TOYODA GOSEI KK) 22 November 1984 -----	

1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IL 96/00096

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A-0357945	14-03-90	DE-A- 3827825	22-02-90
		JP-A- 2082485	23-03-90
DE-A-2505395	19-08-76	NONE	
GB-A-1088543		NONE	
EP-A-0054160	23-06-82	FR-A- 2496235	18-06-82
		AT-T- 8102	15-07-84
WO-A-8704902	27-08-87	DE-A- 3606032	27-08-87
		AU-A- 7032487	09-09-87
US-A-3737624	05-06-73	NONE	
EP-A-0609088	03-08-94	JP-A- 6283261	07-10-94
		US-A- 5493102	20-02-96
		JP-A- 6278244	04-10-94
		JP-A- 6338381	06-12-94
DE-A-3418612	22-11-84	JP-B- 1009714	20-02-89
		JP-C- 1523355	12-10-89
		JP-A- 59214183	04-12-84